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6. AUTHOR(S)

Jeffrey Liker
John Campbell

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Japan Technology Management Program
University of Michigan
Ann Arbor, MI 48109-1290

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The Japan Technology Management Program has carried out research, study, and dissemination activities on Japanese technology management and manufacturing. Activities include publication by researchers of journal articles, publication of a book, fellowships to students to study Japan, student internships in Japanese companies, and workshops, conferences, and study tours for industry personnel.

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Japan Technology Management Program
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Final Technical Report
September 30, 1993 - September 29, 1996

March 24, 1997

Jeffrey Liker and John Campbell
Co-Principal Investigators
300 Lane Hall
University of Michigan
Ann Arbor, MI 48109-1290

The Japan Technology Management Program at the University of Michigan began on September 30, 1991 with a US-Japan Industry and Technology Management Training Program Grant from the Air Force Office of Scientific Research. The stated goal of the training program was to improve American competitiveness by "understanding in detail the management and business practices used by Japan in the areas of science, engineering and manufacturing." The first two-year grant was spent by University of Michigan researchers acquiring knowledge of Japanese technology management practices and in helping engineering, science, and management students gain knowledge of Japan through course work and internships. Some dissemination to industry was also done in publications and conferences.

The grant under which the JTMP operates was renewed for an additional two years in 1993. At that time, the program moved into its second phase, placing more emphasis on dissemination and student training. Research on Japanese technology management practices continued but the emphasis, with some exceptions, narrowed to those areas in which we had the greatest strength and could make the greatest contribution: manufacturing and product development. With a growing reputation for expertise in these two areas, we developed university courses on manufacturing strategies, organized conferences on lean manufacturing and the transfer of Japanese manufacturing practices to the United States, and supported numerous publications, including a book. Faculty and graduate students have taken their knowledge directly to companies, through JTMP-sponsored projects and individual consulting.

The training of students was also strongly emphasized in the 1993-95 grant. (A one-year no-cost extension took the grant to September 1996.) In addition to giving a broad overview of Japanese manufacturing and technology management practices to the many students in University courses we have helped develop, we have also created a small but strong cadre of future engineers and managers who speak excellent Japanese and have a strong understanding of Japanese culture and industry practices. Some of these students are still in school, but others have entered the workforce. While many are bringing their knowledge to companies and universities now, their impact on American industry will not be fully visible for a decade or more, when they are in positions in which they can effect corporate change.

This report is organized around the three broad strategies we have used to achieve the grant goals:

- Research by American experts on management of technology to generate new knowledge about Japan's key practices.

- Dissemination of the results of our research plus broader knowledge of management of technology in Japan to practicing engineers and managers in the public and private sectors.
- Training for students, primarily at the University of Michigan, who will improve America's capacity to learn from and compete with Japan in the future.

RESEARCH AND RESEARCH PUBLICATIONS:

Primary Research Projects

Much of the primary research carried out in the this grant was a continuation of work started in the 1991-93 grant.

Engineering Methods of Product-Process Design This project, directed by Walton Hancock, Professor of Industrial and Operations Engineering, focused on engineering philosophies and practices that distinguish Japan from the U.S., particularly in methods of concurrent engineering, tolerancing, and stamping. Prof. Hancock visited Toyota, Mazda and Nissan to interview several teams of engineers. The results were combined with findings from his ongoing research on American firms and expanded by extensive interviewing in Japanese firms in the U.S. to examine the process control systems for controlling die set, material lot, die maintenance, and assembly variation. Patrick Hammet, then a PhD student in IOE supported by JTMP funds, collaborated on this project.

The two major differences appear to be: a) Japanese engineers have stopped focusing on the interaction between a process and a particular product and have started focusing on the interaction between a generic process and a family of products--a major step forward in concurrent engineering methods. b) The Japanese start out with what the market requires and then proceed to tolerance the individual parts to achieve what the customer wants, rather than the American practice in which specifications are established on parts without much regard to what is appropriate in the particular case. Further, in Japanese firms there is tremendous introspection every time a car is designed, so that the next time the same mistakes will not be made.

The findings have been featured in two continuing education programs and in direct consultation with American firms. Mr. Hammet drew upon this research for his Ph.D. dissertation, in which he took these observations a step further looking at the Japanese manufacturing concept of "functional build." This is a fundamentally different philosophy of auto body design and die manufacture. Normally the design engineer specifies precise dimensions and the die makers build to those precise dimensions. Under functional build the die makers do their best to get close to the dimensions but then stamp out parts, assembly them and make changes to the die so the body meets design intent, e.g., it looks good and meets structural requirements. In this way a great deal of money and time is saved compared to the usual practice of endless grinding of dies. Mr. Hammett's research was done in collaboration with General Motors which funded much of his dissertation research and has continued to fund his research when he took a job as an Assistant Research Scientist in the College of Engineering. There has been great demand

for Mr. Hammett's dissertation and for his consultation services. He is contributing to a broad outreach effort through the auto-body consortium in which the University of Michigan is a key participant.

Concurrent Engineering and Design Process Modeling. This project directed by Allan Ward, Assistant Professor of Mechanical Engineering and Jeffrey Liker, Associate Professor of Industrial and Operations Engineering, and greatly assisted by graduate student Durward Sobek, hypothesized that an accurate model of experienced, successful Concurrent Engineering (CE) teams is one in which teams communicate in ways that can be naturally represented as "sets" of alternative designs. By gradually narrowing the "set" of feasible alternatives, a single design solution is chosen. It is believed that effective CE is enhanced by the use of set-based communication and conceptualization, relative to the process of iterating over point solutions. It is hypothesized that the more experience a company has with CE, the more likely engineers will communicate in terms of sets. Partly for that reason, the Japanese automotive industry appears more proficient at this method of communication, and hence at product development.

The research began with relatively unstructured discussions with teams of design engineers representing different functional areas, at both American and Japanese firms. Forty interviews at ten firms were completed by June, 1992. It was found that companies varied considerably, from those who are beginning to implement CE being strictly "point-based" (e.g. selecting a single alternative, with downstream changes made from this base design), to those who have been practicing CE for 25-30 years being "set-based" (e.g. communicating about sets of alternatives, with downstream changes by reducing the set). The most striking example was an experienced manufacturer-supplier pair designing an engine cooling fan, for which many prototypes were built, and a very high level of design tolerance (20-30%) was maintained until two years before production. Communication was clearly in terms of reducing sets. It is important to note, however, that Toyota is much more advanced in this approach than any other company in Japan as well as in the U.S.

An article by Ward, Liker and associates, "The Second Toyota Paradox," Sloan Management Review, Spring, 1995 has received tremendous exposure in industry with hundreds of requests for reprints and many requests for presentations in industry (e.g., Mack Truck, Steel Case, General Motors, Ford, Whirlpool).

Other outcomes from this project included progress toward a new mathematical formalism for the set-based communication of preference information between concurrent engineering teams, leading to new computational tools that will aid in managing product development processes. The research results have been incorporated into undergraduate and graduate courses, continuing education seminars, and presentations directly to industry (Ford Truck Operations, Ford Electronics Division) and in design seminars. Two graduate students (John Cristiano and Durwood Sobek) received significant research experience working on Japan materials. Recently Dr. Ward, in collaboration with the Industrial Technology Institute, received a major multi-year grant from DOD to continue investigations into set-based design. The focus of this work is in getting representatives of different functional disciplines designing different parts of a product to negotiate for price and space and functional characteristics.

Drawing heavily on the research conducted in conjunction with this work on product development processes, Durward Sobek completed his dissertation on Core Beliefs that Shape Product Development Systems: A Toyota-Chrysler Comparison. Mr. Sobek conducted field research in product development practices at Chrysler Corporation. He then analyzed this data and compared it to the practices of Toyota Motor Corporation. Mr. Sobek spent six months in Japan conducting research at Toyota while affiliated with Nagoya University. There have been so many inquiries about this work that the JTMP will print additional copies of the dissertation to distribute. Mr. Sobek will be presenting in the Traverse City conference next August with an entire day devoted to comparing Toyota and Chrysler's product development systems. Mr. Sobek will present his observations along with representatives from Toyota and Chrysler.

We are also confident that Mr. Sobek will receive offers from publishers to turn the research into a book.

Product Development and Basic Research. As Japan has been catching up to world-class technology in many areas, its research effort has been shifting from applied to more basic objectives. This project studied that process by examining organizational "routines" affecting research, and relationships between researchers and users within and across organizational boundaries. Sites studied in two extended visits in 1992 and 1993 by David Methe, Assistant Professor of Corporate Strategy, include the Central and Advanced Research Laboratories at Hitachi, R&D centers at other firms including NEC and Sony, and the Research Center for Advanced Science and Technology at Tokyo University (which includes industry-endowed chairs).

It appears that even basic research tends to be problem-driven in Japan. For example, a research lab could be asked to work on certain generic or fundamental processes required to improve development of a specific new project. The product may have a timetable for release, or even a target price. Another observation is that, compared with the U.S., there is less likelihood of constantly reinventing the wheel--the organization of labs works better to conserve knowledge once learned.

Prof. Methe has drawn on these findings for several continuing education programs, including Strategic Management of Technology and Negotiating with the Japanese. He has presented his research findings at numerous international conferences and in papers now being considered for major academic journals.

Concurrent Engineering and Defense Procurement. Tom Choi, Assistant Professor of Management at Bowling Green State University and U-M PhD, is conducting a study of concurrent engineering and defense procurement. He has visited several defense contractors to understand how the process of concurrent engineering compares to best practices models from Japanese companies. Choi, along with Jeffrey Liker, is participating in a Government Accounting Office study of commercial practices for shifting products from development to production that might be applied to DOD's acquisition process.

Personal Communication Systems in Japan and Its Potential Effect on Competition in the Wireless Communication Industries, a working paper written by visiting researcher Jeffrey Funk, looked at how competition has evolved after the introduction of technological innovations in wireless communication (analog, cellular, digital cellular)

using the concept of the value network. The paper was a follow-up on a Fulbright-funded study of the wireless communication industries—industries such as wireless communication services, equipment, and telephone—in which Funk had participated while at Pennsylvania State University. That study looked at the past and on-going evolution of technological discontinuities and dominant designs in the wireless communication industries. The major technological discontinuities include analog and digital cellular and personal communication services (PCS). A second paper written while at Michigan also used the concept of a value network to explain the success of incumbents or new entrant in the adoption of analog cellular, digital cellular, or PCS technology. A talk on this subject was presented to the University community.

Management of product families and models in the room air conditioner industry was the subject of another paper written by Funk and under review at *IEEE Transactions on Engineering Management*. The paper utilizes Uzumeri and Sanderson's framework to characterize the evolution of product families and models. The types of methods of creating multi-year and one-year product plans and other methods of coordinating the development of different families and models is characterized using Wheelwright and Clark's framework for product development.

Admittedly, some research projects for which we had great expectation at the start of the funding period did not work out. These were dropped and their resources devoted to other activities.

Faculty Small Grants Program

The faculty fellowships were a new addition for this grant period. One of our goals has been to encourage faculty outside of our core group of researchers and Japan-specialists to look more deeply at Japanese research trends, technological innovations, and management practices, as well as to strengthen ties with leading Japanese research institutions. Many University faculty have an interest in these areas but have been precluded from exploring their interest further due to lack of financial support. We established a faculty fellowship program to give small grants to researchers wanting to add a Japan component to their work. Grants made to faculty could cover research assistance, supplies and materials, or travel. In return, an equal amount of costsharing was required from those receiving funds. Grants were intended to be modest: in the mid four figures.

In the first year of the grant we elected to fund eight of the eleven proposed projects. In the second year, we ultimately supported only one project, although we offered to fund five projects. Nearly all proposals in the two years covered in this report included funds for travel to Japan, which would enable the researchers to see firsthand the work being done on their topic in Japan and to work cooperatively with Japanese researchers. We were pleased that we have received requests from faculty in disciplines with which we have not had much contact: architecture, civil engineering, aerospace engineering, materials science, and physics.

Some of the projects surprised us, as we were unaware of the work being done on these subjects. For example, one team of researchers is working on what they have termed "biobots," insect host fitted with microinstrumentation clusters to be used as

robots and instrumentation lofting devices in environmental engineering. While the concept of using insect hosts for micromachines began in the United States, the Japanese are leaders in microinstrumentation and have begun working in earnest on pairing micromachines with biological hosts. Selden Crary, Associate Research Scientist, in the Department of Electrical Engineering received a grant to visit researchers in Japan.

Most of the projects supported concentrated on technical problems rather than aspects of management of technology. Anthony Waas, Associate Professor of Aerospace Engineering, worked with researchers at the Science University of Tokyo, Mitsubishi Heavy Industries, and Sophia University in the area of compressive strength of composite materials and the need to understand fundamental aspects of mechanical failure in these structures. On the results of this collaboration will be to establish a databank on compressive material properties as well as failure mechanisms of fibrous composite materials. A senior faculty member in the Department of Physics, Joachim Janecke, is participating in an international study of giant resonances in atomic nuclei and traveled to Japan to use an upgraded particle accelerator and new high resolution magnetic spectrometer. To further his own work and to prepare for a new course on intelligent buildings, J.J. Kim, Associate Professor in the College of Art and Architecture, visited Tokyo and Osaka to see firsthand intelligent building technologies in Japan. He examined "smart" buildings in Japan and is now working on a book based largely on his Japan research.

Some of the programs did have a strong management component combined with the technological aspect. A study of the advancement of microelectronic materials and devices in Japan by Stella Pang, Assistant Professor in Electrical Engineering, also included a section on the information and technical exchanges of these technologies between universities and companies. Victor Li, Professor in the Department of Civil and Environmental Engineering, examined the advanced materials technology transfer process in the Japanese construction industry and has produced two papers based on JTMP-supported research. Kathy Stecke, Associate professor of Operations Engineering, gauged the economic and strategic impact of Flexible Manufacturing System in the US, Japan, and Germany.

PUBLICATIONS

The publication highlight of this grant was *Engineered in Japan: Japanese Technology Management Practices*. This volume, edited by JTMP co-directors Jeffrey Liker, John Campbell, and John Ettlie and published by Oxford University Press in 1995, is a compendium of the research conducted in the first two years of the program. In addition to the studies by University of Michigan researchers, we supported the work of researchers at other academic institution to fill in topics we did not adequately cover here. The book covers the technology life cycle from applied R&D to product-process development to manufacturing methods and management. In addition there is a section on technology deployment and organization learning in the US that focuses on efforts in the US to implement Japanese technology management methods. There are 15 research-based chapters plus an introduction and concluding synthesis chapter. There are a total of 31 authors involved, 12 of whom are from other universities in the United States, Canada,

and Japan. Marketed to industry personnel as well as academics, The book was awarded the prestigious Shingo Prize in Excellence Manufacturing Research in 1996.

Two more books are in preparation. In September 1996 the JTMP held an academic conference entitled "Remade in America: Japanese Manufacturing Transformed." The main purpose of the conference was to bring together authors of chapters for a forthcoming book to be edited by Jeffrey Liker, Paul Adler of the University of Southern California and W. Mark Fruin, from the University of British Columbia now visiting at the University of Michigan. The book, *Remade In America: Transplanting and Transforming Japanese Production Systems*, has been accepted for publication by Oxford University Press. As the title suggests this edited book provides broad coverage of the issues involved in bringing Japanese production systems to the United States and the transformations that occur as the systems adapt to the American culture. Prior to the conference all authors wrote drafts of chapters which were circulated. In the conference each author was assigned two other chapters to critique and we provided critical feedback on each chapter.

A second book is being edited by Professor Jeffrey Liker: *Becoming Lean: Experiences of U.S. Manufacturing*. The topic is similar to that of *Remade in America*, focusing on Japanese manufacturing methods implemented in America, but with three important differences: a) The focus of this book is on the Toyota Production System, while *Remade in America* looks more broadly at Japanese manufacturing methods; b) this book is a set of cases of successful implementation written by practitioners--managers or consultants; c) the target audience for this book is practitioners while *Remade in America* is more oriented toward academics. Productivity Press, which is the leading publisher of practitioner-oriented books on Japanese manufacturing methods, has already awarded a contract for the book.

A bibliography of publications is attached to the end of this report.

DISSEMINATION

We have worked on a substantial number of workshops, short course, and university courses specially growing out of our JTMP research. In addition, JTMP researchers have given guest lectures in colleagues courses, introducing our work to even more students. JTMP research has also influenced the content of existing executive education course and executive education seminars.

John Shook, who spent 12 years with Toyota Motor Corp. in Japan and the United States and Mike Rother, a consultant on manufacturing, joined the Japan Technology Management Program part-time in 1994. The program brought them in specifically to facilitate our dissemination of information on lean manufacturing and other Japan-originated manufacturing practices to industry. Not only have they been involved in IOE 425, a course mentioned in the section on student programs, but they have been instrumental in our outreach program. John Shook has spoken to numerous industry groups and consults to companies on lean manufacturing, as well as organized our first Lean Manufacturing Conference. Mike Rother cofounded the concept of Continuous Improvement User Groups and ran one user group of six Detroit-area companies in 1994-

95. CIUGs bring groups of small companies together to learn about continuous improvement methods and actually apply them to production processes. They meet for one day per month, rotating meeting sites across plants in each company. The one-day sessions included some presentations and hands-on training in the shopfloor. Rother has also been running a user group in Mississippi under the auspices of the Mississippi Delta Council and has run a monthly seminar series for small company CEOs in Mississippi.

JTMP faculty and associates Jeffrey Liker, Allen Ward, Durward Sobek, John Shook, and Mike Rother have conducted on-site seminars at each of the automotive Big Three companies under the auspices of the Office of Continuing Engineering Education.

- a) General Motors. GM has an internal continuing education program. Each year they request proposals for degree courses and non-degree short courses. Two of our proposals were accepted for 1-day sessions based on JTMP research. After acceptance of the proposal sufficient enrollment by GM employees is necessary for the course to be held, possibly at multiple sites. GM accepted two JTMP programs. One, on Lean Manufacturing, offered a one-day overview of the Toyota Production System. There was sufficient enrollment to offer the course at five sites in the spring of 1995 and one site in the fall of 1995. The second course, on Toyota's set-based design approach, was adopted by five sites in fall 1995.
- b) Ford. The Ford Production System, modeled on the Toyota Production System, is to be implemented at 160 plants worldwide. Liker, Shook, and Rother have been involved in awareness training on the Toyota production System for top management and all their plant managers.
- c) Chrysler Corporation. Chrysler is also developing a TPS-based system, called the Chrysler Operating System, to be implemented in their 40 North American plants. John Shook has been involved in training on TPS for top management and implementation in pilot programs in plants.

Individual outreach conference and seminars are outlined below:

Japanese Product Development Practices: Lessons from the Auto Industry. This video course, first offered over National Technological University (NTU), was selected by General Motors for their continuing education program. It was offered at the GM Proving Grounds on March 8, 1994. The first five hours were based completely on the tapes, and then John Campbell, Al Ward, and Jeff Liker lead a three hour discussion about the topic more generally. About 15 people watched the program. The live discussion was particularly well received.

Negotiating with the Japanese. This three-day course organized by John Campbell is held twice a year and serves between 18 and 30 people each session. The \$1800 registration fee is waived for DOD employees and we have had eight Air Force employees, usually from Wright Patterson Air Force Base, attend the course. The focus of the course is on negotiating joint ventures, licensing agreements, etc. with counterparts at Japanese companies. Most of the participants have technical backgrounds. The course culminates on the third day in a negotiation simulation in which all attendees participate.

High-Performance Manufacturing Organization: Blending Approached from the US and Japan. This was the third offering of a three-day JTMP course in the Engineering Summer Conference at the University of Michigan, April 20-22, 1994. The course covered Japanese lean production methods as they are being applied in the United States. Many of the speakers were from industry, including speakers from Ford, Chrysler, Eaton Corporation, Whirlpool, Toyota, Nippon Denso, and Rockwell. In all, 48 participants enrolled, mostly from industry, with six from the Department of Defense or government labs. Borg Warner Corp. Sent the entire operating team from one of their Chicago plants that is in the process of converting to lean production methods.

Best Practices in Body-in-White Manufacturing This two-day course was held at the Hyatt Regency Hotel in Detroit in May 1994. The Body-in-White group of JTMP, led by Prof. Walton Hancock, gave presentations of research sponsored by JTM and industrial affiliates. About 150 auto industry managers and engineers attended the course.

Integrated Product Process Development: Product Development through the Supply Chain. The first offering of this two day course was offered as part of the prestigious University of Michigan management Briefing Seminars, the premier event for auto industry executives to learn about current management trends. The course was built off the work of Jeffrey Liker and his associate on the supplier role in product development. There is a growing trend in the United States toward emulating the Japanese keiretsu approach of partnering between auto companies and their suppliers. In addition to JTMP research, there were many automakers and parts suppliers discussing their experience with early involvement of suppliers in the product development. One half-day session focused on Toyota's US product development activities and how they are working with US supplier. The course in 1994 drew 175 customers, making it the best attended of three parallel sessions during those two days and the most successful launch of a new U-M course at the Traverse City conference. This course has continued as an annual event since 1994.

First Annual Lean Manufacturing Conference: Getting to the Core. Held on May 23-24, 1995 in Sterling Heights, Michigan, this conference was attended by more than 100 industry participants. The conference covered the concepts, practices, and implementation issues of lean Manufacturing as a comprehensive system of production. Presenters closely associated with the JTMP included John Shook, Jeffrey Liker, Walton Hancock, and Michael Rother. They were joined by Steve Rasch of the University of Michigan and consultant Russell Scaffede.

Association of Japanese Business Studies Annual Meeting. The JTMP hosted the 1995 meeting of this international academic organization. Jeffrey Liker was the conference chairman. The meeting theme was "Trends in Technology and management." Approximately 125 people from 13 countries attended sessions on various aspects of the Japanese business system, including sessions organized by JTMP-associated faculty. These sessions were "the Future Evolution of the Japanese Business System" (David Methe); Supplier Management for Global Competition (Rajan Kamath); and "Japanese Manufacturing in the United States" (Tom Choi). A special keynote session on "Who's Ahead in the US-Japan Auto Competition" featured auto industry analyst James Harbour, Executive Vice President of Tower Automotive, James Lozelle, and University of Tokyo

Professor Takahiro Fujimoto. Other technology management-related sessions were "Technology Management: Comparative and Historical Perspectives," management of Engineers and Scientists," "R&D Management and Strategy," and "technology Policy." Several papers presented on these topics were included in the conference's "Best papers" volume.

Lean Manufacturing Mission, 1995. John Shook led a one-week study tour of excellent manufacturing plants in the Nagoya area of Japan, the birthplace of the Toyota Production System and lean manufacturing. Sites visited included Toyota and Yamaha. The tour included a pre-departure orientation on Japanese culture and hands-on experience in Standardized Work and kaizen on the plant floor of a Toyota supplier in Nagoya. Seven executives from small to mid-size automotive supplier companies and five University of Michigan faculty joined the tour.

Integrated Product Development Process: Set-based Design. The JTMP returned to Traverse City, Michigan in 1995 for a second year at the Management Briefing Seminars. Set-based design at Toyota was prominently featured in a keynote session with commentary by a Toyota executive in charge of the Toyota Technical Center and another presentation by Toyota was given on their approach to product development. In addition, Allen Ward ran a three-hour workshop on set-based design and Toyota's product development approach.

Lean Manufacturing Mission, 1996. Eleven faculty members, led by John Shook, toured top manufacturing plants in Japan to learn about Lean Manufacturing. Included on the tour were four faculty from the Business School, one faculty member from Mechanical Engineering's manufacturing research laboratory, five faculty from Industrial and Operations Engineering, and one faculty member from the Department of Sociology who teaches on Japanese business. Durward Sobek accompanied the tour. The group visited Toyota, Honda, TOPIX (a kanban system logistics equipment manufacturer), Sony, and Araco (a car seating manufacturer). The group also toured the Toyota Industrial Museum and were given a presentation by Toyota manufacturing managers. The tour was a great success and information learned on the tour has inspired these faculty to include this information in their courses.

Remade in America: Japanese Manufacturing Transformed, a public forum associated with the academic conference, was held in September 1996. Sixty people attended, including 30 from industry. Paul Adler, John Shook, and Mark Fruin were the forum presenters. Jeff Liker moderated.

A workshop that presents the key principles of Toyota's product development system, and demonstrates them through a hands-on design simulation was developed by Allen Ward and Durward Sobek. The workshop was given as part of General Motors' continuing education partnership with the University of Michigan. There has been continuing followup of the workshop with GM, as well as with other companies.

TRAINING STUDENTS

The training of students has been a core mission of the Japan Technology Management Program and often one of the most rewarding. We have had contact with several hundred students in the last four years. Sometimes that contact has been fleeting, such as referral to language programs in Japan, but in some significant cases the JTMP has had a major impact on a student's career.

Research Assistantships

Research Assistantships bring graduate students into the research process and are one of the best vehicles for faculty mentoring of students. The JTMP supported five research assistantships in engineering and two in business administration. Two of the engineering assistantships were fully supported with funds from other sources.

Four of the Engineering assistantships, all in Industrial and Operations Engineering, went to students studying with our core JTMP faculty. John Neale worked with Izak Duenyas on his study of scheduling approaches for microcircuit production. John Cristiano continued his research on the use of Quality Function Deployment in the US and Japan and is developing an extension of QFD using decision analysis methods. Patrick Hammet completed his PhD research on the die development and tryout process for a General Motors plant. Durward Sobek spent six months in Japan learning about product development at Toyota. The fifth engineering student, Tim Chang, was in the doctoral program in Electrical Engineering. The JTMP had supported Mr. Chang for language study and an internship at Toyota and wanted to encourage his interest in combining his interest in Japan and broader management issues with his engineering studies. He left, however, after one term to pursue a job with General Motors in Tokyo.

The two Business Administration students were in the MBA program. Both were exceptional students enrolled in the Michigan Joint Manufacturing Initiative Program, a joint program between Business Administration and Engineering focused on training future leaders in manufacturing. Both Tim Fisk and Andrew McKenna had worked for several years in Japan as engineers. They assisted Business School faculty on Japan-related research projects.

Student Fellowships

The JTMP has offered fellowships for language and cultural training since its inception. The fellowship program has expanded and now includes support for research on Japan. At all times we have tried to be flexible, entertaining any reasonable proposal for student support. While we have been generally happy with the students we have supported under this grant, we have been concerned to see the numbers of applicants for our fellowships fall significantly, from more than 80 in 1992 to 19 in 1996. This seems to be a nationwide phenomenon. Despite the falling number of applicants, and subsequently of fellowships awarded, we have been able to keep up the quality of the students we have supported. These fellowship programs are heavily supported with costsharing dollars by the College of Engineering, Business School, College of Literature, Science, and the Arts, and School of Graduate Studies.

Fellowships fall into several major categories, which are discussed below. The summer fellowships fall within the original funding period of the grant. The second year

of funding for academic year fellowships necessarily was supported under the grant's no-cost extension.

Summer language fellowships. Students are awarded funds to study Japanese language at the University of Michigan's Summer Intensive Japanese Language Program or at the Japan Center for Michigan Universities in Shiga, Japan. Fellowships provide students with tuition, fees, and a living stipend. Students going to Japan are also given airfare. In summer 1994 15 students were funded for the U-M language program. Nine of these students were engineers, two at the graduate level. Of the remaining six recipients, all but one were in the MBA program (including four in the joint MA program in Japanese Studies), of whom three had technical backgrounds. The sixth recipient was a sociology PhD student studying the history of science and technology policy in Japan. Six of the summer students were from other universities. Eight students were in the third year Introduction to technical Japanese course, one was in regular third year Japanese, three were in a second year, and four were in first year. Five students were selected to study in Japan. Two studied at the fourth year level at JCMU and one studied at the second year level there. Two students attended the EAGLE Japan Program. The final student, an newly graduated materials engineer, was sent to the Pittsburgh summer program in preparation for spending the academic year at Kyushu University. (Pittsburgh waived tuition and fees and the JTMP supplied a stipend.) In summer 1995 we funded a total of seven students. Five of these students studied at U-M. One attended the JCMU and one participated in the EAGLE Japan Program in Kanazawa, Japan. Four of these students were graduate students and one was an undergraduate.

Language study incentive fellowships. These modest fellowships of \$750 per term are offered to encourage engineering students to continue with Japanese language training beyond the second year. Three students received these fellowships in 1994-95 and four received them in 1995-96. As doctoral students pay tuition by the number of credits taken, they are often reluctant to take language courses for financial reasons. To encourage their continued study of Japanese, we offered language course tuition waivers to two graduate students taking fourth year technical Japanese.

Academic Year Japan Studies Fellowships. These fellowships, which offer tuition, fees, and a living stipend for a full academic year, are offered in order to produce engineers, scientists, and managers who are knowledgeable about the culture and society of Japan, as well as the language. Students receiving these fellowships spend an additional year of graduate studies taking language and areas studies courses. Often students elect to enter the Center for Japanese Studies master's degree program. four fellowships were offered in the 1994-95 academic year and four in 1995-96. They were split evenly between engineering and business school students.

PhD Support Fellowships. Recognizing that much important work is being done on Japanese technology management at the doctoral level, we made fellowships available for students doing substantial dissertation work on Japan, with support proportionate to the Japan content of their research. Two students in 1994-95 and three students in 1995-96 were supported with these fellowships, all from the Department of Industrial and Operations Engineering.

Research Support. These fellowships provide students the means to conduct significant research projects on Japan, usually a doctoral dissertation or master's thesis. The funds can cover travel, survey printing and mailing costs, archival data, and other expenses connected with a research project. We provided travel funds for two students doing doctoral work on microelectronics and for a Japanese studies master's student conducting research on an area of Japanese business law. These grants have typically been quite modest.

Miscellaneous Support. As we endeavor to be flexible so that we can best serve the needs of our students and the program, we have given a number of grants that do not fit neatly into the above categories. This includes language tutoring for MBA students whose business curriculum prevents them from enrolling in regular language courses. We also used fellowship funds to send two students on a lean manufacturing training seminar at the University of Kentucky.

Internships

We strongly believe that the best way for students to learn about Japan and encourage a long-term commitment to involvement with Japan in their work life is through internships. Despite the economic recession in Japan, we were able to place eight students in summer internships in 1994 and six in 1995. In general we require that students have three years of Japanese so that they can communicate comfortably, if not fluently, on the job. Several companies have accepted one or more of our students nearly every year: Toyota Motor Corporation; Aisin Seiki, a major Toyota supplier; Long Term Credit Bank of Japan Research Co.; and Sumitomo Metals. We have also occasionally been able to place students at other companies or institutions, such as the United States Embassy Science and Technology Office in Tokyo, Mitsubishi Corporation, Fuji Xerox, the Nihon Keizai Koho Senta (Japan Economic Research Council Center), and the Human Factors Engineering Laboratory at Hiroshima University.

Interns tend to be a mix of engineering, business, and social science students. Quality of internships also vary from company to company and even year to year within a company depending on the project supervisor. Some students are given demanding and interesting projects on which to work. For example, in 1995 Thuan Lieu and Michael Martin worked on the CFD analysis of solar car proposals at Aisin Seiki and Tim Chang helped design controls for in-car multi-media systems in the Electronics Engineering Division at Toyota. Other internships, particularly in management, can be frustrating for the students as they are given little or no real work to do. We try to prepare students for this possibility by encouraging them to design an independent research project that they can conduct while at the company, urge them to partake in as many company activities as possible so they can sharpen their language skills, and then at the end of the summer help them assess what they have learned about Japanese business. They are often surprised to find that they learned much more than they thought they had. One conclusion most of our students have come to, however, is that though they want to remain involved with Japan and perhaps work for a few years at a Japanese firm, they do not want to spend their careers in a Japanese company.

Courses

Research conducted under the auspices of the JTMP is disseminated to a wide group of students in the courses taught by the researchers and by guest lectures of these researchers in colleagues' classes. The Department of Industrial and Operations Engineering now offers two courses that would not be taught were it not for the Japan Technology Management Program.

IOE 425: "Manufacturing Strategies." John Shook taught a section of this course within the Department of Industrial and Operations Engineering, focusing on Lean Manufacturing and its dissemination in the United States. The course included lectures, discussion, video presentations, and plant visits to local Japanese and American-owned manufacturing firms. Approximately 50 students were enrolled in winter semester from various departments in the College of Engineering, the School of Business Administration, and College of Literature Science and the Arts, as well as from industry. The course has proven so popular that it will be taught in both Fall and Winter semester of the 1995-96 academic year and still has a waiting list.

IOE 591: "Japanese Technology Management." This course was introduced in Winter 1994 and was again taught by Jeffrey Liker in Winter 1995. The course attracted 25 masters and Ph.D. level students. It received high teaching evaluations. In addition to presentations and discussion in class, a trip was made to the Toyota Technical Center and to NSK's manufacturing operation in Ann Arbor.

Technical Japanese

The third and fourth year technical Japanese language courses thrived in the second-round grant, though courses remained relatively small with ten or fewer students. The courses' instructor, Keiko Unedaya, has been very active in interacting with Japanese language teachers throughout the country to develop curricula and materials for the teaching of Technical Japanese. In addition she is working on a technical Japanese textbook, which should be ready for publication within a few months and is an instrumental member of a computer-aided instruction project which also includes members from Tsukuba University, University of Pittsburgh, Purdue University, University of Washington, and MIT. This project on the development of the a system for teaching and evaluating reading skills in scientific and technical Japanese is funded by the Japanese Ministry of Education.

CONCLUSION

The second grant period for JTMP was highly productive continuing all of the work started in the first grant period on research and student support and expanding significantly our outreach activities. Over time many of the researchers who JTMP helped fund have gone on to get additional outside support to build on what they started through JTMP. The program has received national attention and is becoming well known as a resource to industry in the Midwest. In the third grant period we are continuing all of the programs we started and also continuing to evolve our outreach activities which also will provide support to sustain the program beyond AFOSR funding.

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